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FLAVOUR REVERSION IN HYDROGENATED LINSEED OIL

II. EFFECT OF VARIATIONS IN PROCESSING PROCEDURES[1]

BY H. W. LEMON[2], A. LIPS[3], AND W. HAROLD WHITE[4]

Abstract

Shortenings prepared from various linseed oils by different methods were stored at 43.3° C. (110° F.) and sampled at eight-week intervals for 56 weeks. Storage life in terms of flavour reversion was not highly correlated with mean peroxide value or unsaturation. All shortenings were resistant to normal oxidation, but unstable to reversion unless hydrogenated to a very low iodine number. Hot and cold pressed oils yielded products equally susceptible to flavour reversion. Changes in stability attributable to variations in methods of alkali refining, bleaching, and hydrogenation were only minor. High alkali concentrations (30° to 40° Bé.) were beneficial, while hydrogenation at 190° C. (374° F.) was preferable to hardening at lower temperatures (140° C. (284° F.) and 115° C. (239° F.)). Blending with other vegetable oils, or the use of hydroquinone or a wheat-germ oil preparation as antioxidants, slightly retarded the onset of reversion. None of the laboratory or commercially prepared samples examined was considered to be a satisfactorily stable product.

In the previous paper in this series (5) data were presented which indicated that the presence of an isomeric linoleic acid, produced by hydrogenation of linolenic acid, was responsible for flavour reversion in shortenings made from linseed oil. The present paper deals with a parallel investigation, involving long-term storage studies, of the effect of various modifications in processing technique upon the susceptibility of linseed oil shortenings to reversion.

Experimental

The material selected for study consisted of hot and cold pressed raw linseed oils from representative Canadian mills; a commercial raffinate obtained by solvent segregation of refined linseed oil; refined cottonseed and sunflower seed oils; and commercial shortenings manufactured from linseed oil. Except where otherwise stated, experimental shortenings were prepared from the same batch of cold pressed raw linseed oil, according to standardized processing procedures.

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Standard Processing Technique

Four and one-half times the quantity of 30° Bé. sodium hydroxide solution required for neutralization of the free fatty acids was added to raw linseed oil with stirring (80 r.p.m.) and agitation continued for 45 min. at room temperature. The rate of stirring was then reduced to 18 r.p.m. and the temperature raised as rapidly as possible to 65° C. (149° F.). Stirring was continued for 30 min., and the mixture allowed to stand for 60 min. before cooling. The decanted refined oil was filtered, using 0.75 to 1% diatomaceous earth as a filter aid. The foots were quite soft and entrained an appreciable amount of oil, causing a considerable refining loss. However, much of this oil could be separated from the foots by centrifuging. The free fatty acid content of the refined oil was of the order of 0.01% (expressed as oleic acid).

The clear refined oil was mixed with 3% of activated clay and 0.6% of activated carbon; it was agitated at 70° C. (158° F.) for 30 min. and filtered.

The bleached oil was hydrogenated in an apparatus previously described (5), at a temperature of 140° C. (284° F.) and a pressure of 25 lb. of electrolytic hydrogen. A nickel formate catalyst on a diatomaceous earth carrier, reduced in cottonseed oil with hydrogen at 265° C. (509° F.), was used in a concentration of 0.25% as nickel. The course of hardening was followed by determinations of refractive index with a Zeiss butyro-refractometer. Hydrogenation was stopped between iodine values 70 and 80. Before filtration at 100° C. (212° F.), a small amount of activated carbon was added to the oil-catalyst mixture in order to secure a clear filtrate.

Hydrogenated samples were steam-deodorized for three hours at a temperature of 200° C. (392° F.) and a pressure of 2 to 4 mm. of mercury.

Tests on Shortening Materials

Storage

Samples were stored in loosely covered glass jars at 43.3° C. (110° F.) in the absence of light, and were sampled at eight-week intervals for 56 weeks. The odour of stored samples was rated by a 10 member panel. Samples were considered to be unacceptable when five of the judges scored the material as definitely reverted. From these data the storage life in weeks was estimated statistically, except in a few cases where irregularity of the observations made graphical interpretation necessary.

Heat Test

A rapid test for reversion was employed on some of the freshly prepared materials. Samples (20 gm.) were weighed into 100 ml. beakers and heated in an oven at 200° C. (392° F.) for three one-hour periods. The odour was noted when the sample was hot, and again when it had cooled. The odour of linseed oil shortening tested in this manner is stronger and more uniform than that which develops during storage at lower temperatures, and is similar to that which occurs in baked products containing linseed oil shortening. This intensification of odour may be due to oxidation or other further decomposition

caused by the heat treatment. All hydrogenated linseed oil samples except those having very low iodine numbers developed this odour. Since the differences observed among samples in the shortening range (iodine value 65 to 80) were not great, regardless of the method of processing, this test was used only in a qualitative way.

Baking

With the co-operation of Mr. A. G. O. Whiteside of the Cereal Division, Dominion Central Experimental Farm, Ottawa, a number of linseed oil shortenings were tested in bread at a level of 4% of the weight of the flour. Both the bread and toast prepared from it were tasted by panels. Differences among bread samples containing various linseed oil shortenings were not significant, even with shortenings which differed markedly by the rapid heat and storage tests. It was thought that toasting might accentuate any differences in the stability of the shortenings, but this was not observed to be the case. Hence, the bread baking test was considered to be of little value in assessing relative resistance to flavour reversion of linseed oil shortenings.

Chemical Determinations

Peroxide oxygen at each sampling time was determined by a modification of Lea's method (3). Saturated and iso-oleic acids were estimated by the lead salt precipitation method of Baughman and Jamieson (2). For iodine numbers Wij's method (4) was employed.

As none of the chemical measurements was correlated highly with storage life as estimated in terms of resistance to flavour reversion (Table I) these data are not presented in detail. In all linseed oil shortening samples, flavour reversion was well advanced before peroxide value showed any marked increase. Storage life and iodine value were not significantly correlated, but there was some indication that stability to flavour reversion might decrease

TABLE I

SIMPLE COEFFICIENTS OF CORRELATION BETWEEN MEASUREMENTS ON 36 LINSEED SHORTENINGS

Quantities correlated	r
Storage life with:	
Mean peroxide oxygen value	.13
Iodine number	−.35
Saturated acids content	.05
Iso-oleic acid content	.39*
Iodine number with:	
Mean peroxide oxygen value	.05
Saturated acids content	−.86**
Iso-oleic acid content	−.63**

* *Indicates 5% level of significance.*
** *Indicates 1% level of significance.*

with increasing unsaturation. Storage life was significantly related to iso-oleic acid content. As expected, iodine value correlated highly with both saturated and iso-oleic acids contents.

Variations in Processing Procedures

The estimated storage lives, together with the calculated necessary differences, for shortening samples prepared by various processing techniques are presented in Table II.

Hot and Cold Pressed Oils

Samples of six hot and seven cold pressed oils from four companies were treated by the standard procedures outlined above for refining, bleaching, hydrogenation, and deodorization.

Storage tests (Table II (*A*)) revealed that hot and cold pressed oils yielded products equally resistant to flavour reversion; i.e., the six hot pressed oils had an average keeping time of 33 weeks, the seven cold pressed, 32 weeks. No definite differences could be detected by means of the rapid heat test.

Effect of Sodium Hydroxide Concentration in Refining

Cold pressed linseed oil was refined with 5°, 10°, 20°, 30°, and 40° Bé. sodium hydroxide solutions. The amount of sodium hydroxide in proportion to the weight of oil was kept constant, so that the only variable was the water content. Attempts were also made to refine raw linseed oil with saturated sodium hydroxide solution and with sodium hydroxide flakes. The refined oils were bleached, hydrogenated, and deodorized.

Reference to Table II (*B*) indicates that the use of the higher alkali concentrations in refining tended to retard the onset of flavour reversion in the hardened material. This result was partially confirmed by the rapid heat test, where five out of seven persons considered the product from oil refined with 40° Bé. lye to be superior to that treated with 5° Bé. lye.

When a saturated sodium hydroxide solution was used, the resulting refined oil was dark in colour, and foamed badly during hydrogenation and deodorizing. With sodium hydroxide flakes, the oil was not neutralized unless violent agitation at about 70° C. (158° F.) was employed. This procedure caused darkening of the oil. Furthermore, the soap was so finely dispersed that its separation from the oil was very difficult. It was concluded that it was impractical to use sodium hydroxide solutions stronger than 40° Bé.

Bleaching

One series of cold pressed oils, refined with 30° Bé. lye, was bleached with 1, 3, and 5% of activated clay, and another series with the same concentrations of activated carbon. Each oil was hydrogenated and deodorized in the usual manner. An unbleached sample was processed at the same time as a control.

Table II (*C*) shows that the use of less clay and more carbon in the standard bleaching process should be beneficial.

TABLE II

STORAGE LIFE AT 43.3° C. (110° F.) OF LINSEED SHORTENINGS PREPARED BY VARIOUS PROCESSING PROCEDURES, IN TERMS OF WEEKS BEFORE THE APPEARANCE OF DEFINITE REVERSION

Group	Group variant	Storage life, weeks
A. Hot and cold pressed linseed oils	Hot pressed	27
	Hot pressed	39
	Hot pressed	16
	Hot pressed	31
	Hot pressed	45
	Hot pressed	42
	Cold pressed	29
	Cold pressed	30
	Cold pressed	34
	Cold pressed	34
	Cold pressed	32
	Cold pressed	38
	Cold pressed	33
B. Effect of concentration of sodium hydroxide solutions in refining	5° Bé.	25
	10° Bé.	35
	20° Bé.	40
	30° Bé.	50
	40° Bé.	42
C. Effect of bleaching agents	Unbleached	31
	1% clay	29
	3% clay	35
	5% clay	0
	1% carbon	37
	3% carbon	33
	5% carbon	42
D. Hydrogenation to various iodine values	161.6	0
	133.5	9
	92.0	26
	57.3	15
	38.1	24
	6.1	60 +
E. Catalysts, at different temperatures	Commercial *A*, 115° C.	38
	140° C.	36
	190° C.	57
	Commercial *B*, 115° C.	47
	140° C.	42
	190° C.	53
	Commercial *C*, 115° C.	52
	190° C.	58
	Commercial *D*, 140° C.	11
	190° C.	5
	Oil-reduced formate, 115° C.	31
	140° C.	39
	190° C.	43
	Dry-reduced carbonate, 115° C.	33
	190° C.	42

TABLE II—*Concluded*

STORAGE LIFE AT 43.3° C. (110° F.) OF LINSEED SHORTENINGS PREPARED BY VARIOUS PROCESSING PROCEDURES, IN TERMS OF WEEKS BEFORE THE APPEARANCE OF DEFINITE REVERSION—*Concluded*

Group	Group variant	Storage life, weeks
F. Blends with sunflower seed oil	100% linseed	27
	75% linseed	24
	50% linseed	27
	25% linseed	27
	0% linseed	28 (rancid)
G. Antioxidants	Formula *C*, 0.1%, before hydrogenation, hot pressed oil	38
	Formula *C*, 0.1%, before hydrogenation, cold pressed oil	26
	Formula *C*, 0.1%, before bleaching	23
	Formula *C*, 0.1%, before hydrogenation	21
	Formula *C*, 0.1%, before deodorizing	26
	Formula *C*, 0.1%, after deodorizing	45
	Hydroquinone, 0.02%, before bleaching	23
	Hydroquinone, 0.02%, before hydrogenation	27
	Hydroquinone, 0.02%, before deodorizing	26
H. Linseed oil raffinate	Raffinate, unbleached	31
	Raffinate, bleached	35
	Raffinate, hydrogenated by a commercial firm	41
Necessary difference	For storage life 0 to 35 weeks	10
	For storage life 35 to 60 weeks	16

Hydrogenation to Various Iodine Values

Refined and bleached cold pressed oil was hydrogenated to the following iodine values: 162, 134, 92, 57, 38, and 6. All the products and also a sample of unhydrogenated oil were deodorized.

By the use of the rapid test it was found that the unhydrogenated oil and the sample having an iodine value of 162 both developed a strong "painty" odour on heating. At an iodine value of 134 the painty odour was almost gone, but the characteristic reversion odour could be detected. The reversion odour was at its maximum at iodine value 92, definitely less at 57, almost absent at 38, and definitely gone at iodine value 6. It has been pointed out that the intensity of this odour roughly parallels the accumulation and disappearance of iso-linoleic acid (5).

The storage data presented in Table II (*D*) in general corroborate the observations of the rapid test. However, the differences for the middle range of iodine values are not significant.

Hydrogenation with Various Catalysts at High and Low Temperatures

Four commercial and two laboratory prepared nickel catalysts were tested. The preparation of oil-reduced nickel formate has been described in the section on standard methods. Dry-reduced nickel carbonate was prepared as follows. Nickel nitrate was dissolved in water, and a quantity of diatomaceous earth added. Sodium carbonate solution was added slowly and in excess while the mixture was stirred. The precipitate was collected by filtration, washed with water, and dried. The dry powder was reduced at 400° C. (752° F.) for three hours in an atmosphere of hydrogen. When cool, it was quickly transferred to melted shortening. The nickel content of each catalyst was determined, and quantities equivalent to 0.1% nickel on the weight of the oil were employed. The catalysts were tested at 115°, 140°, and 190° C. (239°, 284°, and 374° F.).

According to the storage (Table II (*E*)) and rapid heat tests, only one of the six catalysts studied, commercial sample *D*, was definitely unsuitable; however, this catalyst was not intended for hydrogenation of oils. Of the other catalysts, the commercial products appeared to yield more stable shortenings than did the laboratory prepared materials. These differences were significant in several cases. Hydrogenation at 190° C. (374° F.) produced shortenings with longer storage lives as compared to hydrogenation at the lower temperatures. This increase was significant only in the case of commercial catalyst *A*, but a general trend towards increased stability with higher hydrogenation temperatures was observed.

Blends

Refined and bleached cold pressed linseed oil and refined sunflower seed oil were used in the preparation of a series of pure and blended oils, as follows: (i) 100% of linseed oil, (ii) 75% of linseed oil, 25% of sunflower seed oil, (iii) 50% of linseed oil, 50% of sunflower seed oil, (iv) 25% of linseed oil, 75% of sunflower seed oil, (v) 100% of sunflower seed oil. A similar series of blends of linseed oil with cotton seed oil was prepared. Each oil, or combination of oils, was hydrogenated and deodorized in the usual manner.

In rapid heat tests, as expected, the typical odour of reversion decreased as the proportion of sunflower oil was increased. However, the storage tests (Table II (*F*)) did not reveal any significant differences, as the hydrogenated sunflower seed oil component was no more resistant to rancidity than the linseed shortening itself was resistant to flavour reversion. Similar results were obtained with the series of cottonseed oil blends, for which storage lives are not reported.

Use of Antioxidants

Two antioxidants were used: Formula *C*, a wheat-germ oil preparation (6), in a concentration of 0.1%; and hydroquinone, in a concentration of 0.02%.

These were added (*a*) before bleaching, (*b*) before hydrogenation, (*c*) before deodorizing, and (*d*) after deodorizing. Formula *C* was also tested in shortenings made from samples of hot and cold pressed oils which were refined by means of a special silica-gel–alumina adsorbent (1).

Table II (*G*) shows that the only instance in which the added antioxidant significantly increased the storage life over the average for standard processing (32 to 33 weeks) was with formula *C* after deodorizing. This was confirmed by rapid heat tests.

Commercial Products

A commercial linseed oil raffinate, obtained by solvent segregation of refined linseed oil, was hydrogenated and deodorized in the standard manner. A shortening prepared from this oil by a commercial firm was included in the tests. Two other commercial shortenings purported to be made from a 100% linseed oil base were also examined.

The commercial raffinate had a lower iodine number than any of the linseed oils used, and therefore required less hydrogenation. However, the product, when heated to 200° C. (392° F.), developed the same unpleasant odour that is characteristic of hydrogenated linseed oil, and the storage life was no better than that of the linseed oil shortenings prepared in the laboratory. A shortening prepared from this oil by a commercial firm had a somewhat longer storage life (Table II (*H*)).

The two commercial linseed oil shortenings developed the usual reverted odour in the rapid heat test. Bread baking tests at the Dominion Central Experimental Farm confirmed this finding. No storage data were obtained.

Discussion

The results of these studies indicate that variations in the usual fat processing techniques do not yield a satisfactory solution to the problem of flavour reversion in linseed oil shortening. The product reverted readily when heated to baking or frying temperatures unless it had been hydrogenated to a very low iodine number. When it was stored at lower temperatures, differences in stability induced by changes in treatment were more readily estimated, but most of these differences were not significant.

Some slight improvements in stability may be obtained by modifications of the customary processing procedures, but it appears that the difficulty of flavour reversion in linseed oil shortening should be attacked at its source, the tri-unsaturated components of the linseed oil, in line with the iso-linoleic acid formation theory already developed (5). Separation of a major portion of the linolenic glycerides from the oil prior to hydrogenation, or a more selective hydrogenation to minimize the formation of iso-linoleic constituents, would seem to be indicated.

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A SIMPLE METHOD OF SEALING GAS- OR VACUUM-PACKED TINS[1]

By W. A. Bryce[2] and H. Tessier[3]

Abstract

A method of soldering tins in a gaseous atmosphere or in a vacuum is described. The heating element is a coil of resistance wire supported over a hole in a flat surface of the tin. When the heating circuit is closed, a small piece of solder previously hung in the upper end of the coil is melted and drops on the area about the hole and thereby produces an effective seal.

Introduction

The need for a method of sealing gas- or vacuum-packed tins arose in this laboratory in connection with studies being conducted on the storage of dehydrated foods. Previous investigators (3) have used glass containers for vacuum packing. Gas packing of egg powders has been done by soldering the containers immediately upon removal from the gas chamber, assuming that the sorption of carbon dioxide or nitrogen was slow enough to permit sealing without oxygen intake. However, further investigations (2) have shown that the sorption of oxygen by milk powders is sufficiently rapid to make the above method of questionable value.

A method (1) of sealing tins by means of a soldering iron extending into a desiccator was found to be slow and cumbersome. An effort was therefore made to devise a faster and more convenient technique. This paper describes the method developed for sealing tins in either gas or vacuum.

Description of Apparatus

The method devised employed a soldering technique using a small coil of resistance wire as a heating element. A sealing unit is shown in Fig. 2.

The coil was made from six inches of No. 18 chromel *C* wire and had two half-inch turns in the lower part and six smaller turns in the upper. When the coil was in position the lowest turn rested on the flat surface of the tin. The coil was connected to the external circuit by two binding posts mounted on a bakelite platform. The platform was supported by a metal extension attached to one side of a small battery clip, the jaws of which had been shaped to fit the contour of the protruding rim of the container, thus holding the apparatus in position.

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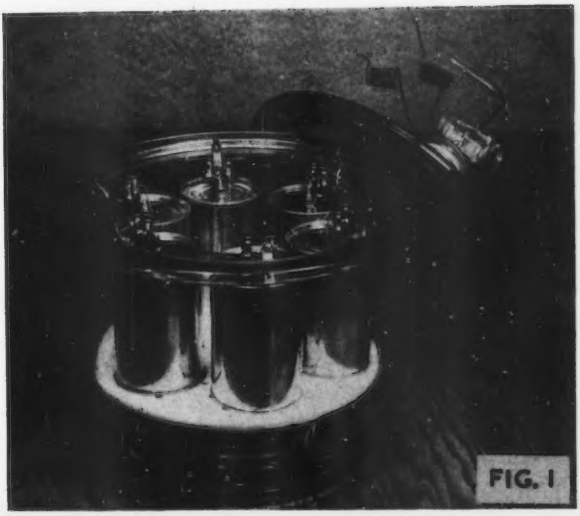

FIG. 1. *Tins, with soldering devices attached, in position in a vacuum desiccator.*
FIG. 2. *The soldering apparatus in position on a tin.*
FIG. 3. *An example of the seal obtained under vacuum.*

Procedure

The material under investigation was canned, using a suitable canning machine. A small hole, approximately $\frac{1}{16}$ in. in diameter, was then made in the centre of one end of the tins. The surface of the tins was lightly etched with sandpaper to obtain better soldering conditions. A suitable number of tins, each with its own soldering coil, was placed in a vacuum desiccator containing a porcelain plate as a supporting base. The tins were insulated from each other. The soldering units were then connected in series, the power leads passing out of the desiccator through the rubber stopper supporting the air-outlet stopcock. A $\frac{1}{4}$ in. length of acid core wire solder was placed in the upper end of each coil, one end of the solder 'bullet' being flattened to prevent it from dropping through the coil. Fig. 1 shows the assembly with the tins and soldering units arranged and the desiccator ready for sealing.

When the desired vacuum or gas composition was attained, the stopcock was closed and a potential applied across the external power leads, causing the solder bullets to melt, drop down, and seal the holes in the tins. The surface of the tins around the holes had been heated by contact with the lowest turn of the coil, thus ensuring proper conditions for soldering. After the few seconds required to melt the solder and seal the tins, the heating circuit was opened, the pressure brought to atmospheric, and the sealed tins were removed.

The entire operation can be completed in half an hour. An example of the type of seal obtained is shown in Fig. 3.

Discussion

The simplicity of the method makes it readily applicable to laboratory studies. The limit to the number of tins that can be sealed simultaneously obviously depends on the dimensions of the vacuum chamber, the size of the tins, and the power source available. The apparatus described above may be used on larger tins by making suitable alterations in design.

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A LABORATORY HULLER FOR SUNFLOWER SEED AND OATS[1]

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Abstract

A laboratory huller of the centrifugal impact type is described and test data on sunflower seed and oats are given using percentage of seed hulled and meats broken as criteria of efficiency. It is shown that hulling efficiency is a function of impact velocity and moisture content of the seed. Low moisture levels give almost complete hulling with high meat breakage while higher moisture levels give practically no breakage of meats but lower levels of hulling.

By selecting proper conditions of moisture and impact velocity it was possible to obtain 90 to 95% hulling with less than 10% of broken meats. It is suggested that improved efficiency might be obtained by flash drying to render the hulls more brittle without affecting the moisture level in the meats.

In commercial processing of sunflower seed, the hull, which constitutes 40 to 50% of the seed, is removed prior to crushing. This results in a reduced bulk of material to press, a higher oil yield, better oil quality, and a press cake that meets requirements for a high protein concentrate. Obviously, practical laboratory data on sunflower seed should be expressed on a hull-free basis. To attain this objective and since no small scale equipment was available, work on the design and construction of a laboratory huller was undertaken.

A commercial hulling installation consists of a sizing or grading unit, a huller, a beater, a set of sieves, and an aspirating unit. It is designed for continuous operation and even if constructed on a laboratory scale would have serious disadvantages. In handling small samples it is not feasible to size the material and in the complex separating equipment losses would be too high to yield quantitative data. Furthermore, the time and work required to clean the equipment between samples would detract from its usefulness.

A practical laboratory huller must be simple to construct and operate, give a high percentage of hulling, yield a product easily resolvable, and be self-cleaning. If a unit can be devised to operate effectively on ungraded seed with minimum breakage of kernels, it should be possible to reduce the equipment for sunflower seed to a hulling unit plus a simple fanning or aspirating unit.

Commercial hullers are of three main types: impact hullers, constructed like a rub-bar threshing cylinder; disk or burr hullers, built on the principle of an attrition mill with the plates set to crack the seed without breaking the meats; and cutting hullers designed like a Wiley mill with adjustable clearance between the knives. The effectiveness of all these machines depends on the clearance between the hulling surfaces or knives and for any setting there is

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an optimum seed size. Hence, for most efficient operation the seed must be graded and the huller adjusted for each grade. Even when this is done, hulls and meats are subjected to mechanical breakage before discharge from the huller and this complicates the problem of separating the mixture.

A hulling unit, designed to minimize these difficulties, was constructed and has been operated successfully for two years in this laboratory. It consists essentially of a rotating disk, which throws the seed against a fixed impact surface set at an angle to deflect the hulled material out of the course of unhulled seed issuing from the rotor. With this arrangement seeds are individually subjected to a single sharp impact and immediately removed from further breakage in the huller.

The following sections of this paper present details of construction and test data obtained on sunflower seed and oats.

Equipment

A section drawing of the essential mechanism is shown in Fig. 1. The rotor spindle, *E*, and motor, *M*, are solidly bolted to a 2 in. × 6 in. board, which is, in turn, supported by a rectangular base of 2 in. × 4 in. wood stock.

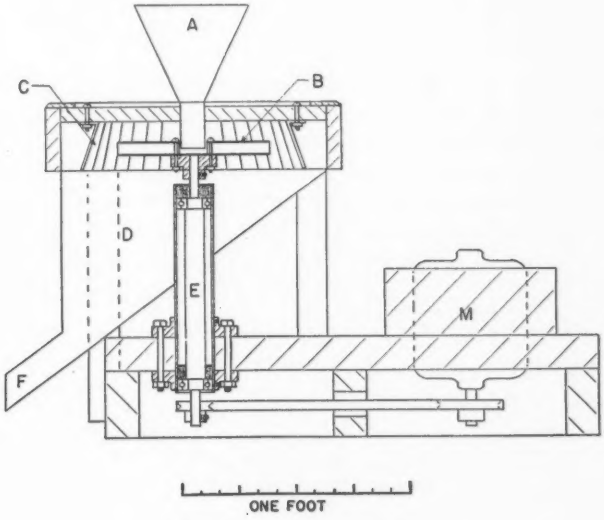

FIG. 1. *Section drawing of huller.*

Four uprights carry a wooden frame that supports a sheet metal collector, *D*. A plywood cover is fitted with a feeding device, *A*, and a circular baffle, *C*.

Seed is fed at *A* directly into rotor *B*, which is mounted on spindle *E*. It is impelled through channels in the rotor and strikes baffle *C* where it is

hulled. Immediately after impact the material is deflected downward into collector *D* and delivered through spout *F*.

Rotor *B* consists of two 16-gauge galvanized iron disks 8 in. in diameter mounted $\frac{5}{8}$ in. apart with metal spacers that form six channels running from a central opening in the upper disk to the periphery. The assembly is bolted to a flange mounted on spindle *E*. This spindle is constructed of steel boiler tubing and carries two $\frac{3}{4}$ in. sealed ball-bearings packed in grease. It is driven by a compound wound, $\frac{1}{4}$ h.p., d-c. motor through a $\frac{1}{2}$ in. V-belt. By inserting suitable variable resistances, either in the field or the armature circuit of the motor, speeds ranging from 1200 to 4000 r.p.m. are readily obtained.

The impact baffle *C* consists of 25 pieces of $\frac{1}{16}$ in. metal $1\frac{1}{4}$ in. wide bolted to the cover. These strips are bent at an angle of 20° away from the rotor and curved to form a continuous circular surface $1\frac{1}{2}$ in. from the edge of the rotor. An alternate baffle can be constructed from a truncated cone of 8 × 8 mesh, 16-gauge, scouring screen. The latter construction is easier to fabricate and gives essentially as good or better performance.

The feeding hopper, *A*, passes through a tightly fitting sleeve in the cover. By moving the hopper vertically the clearance between it and the lower disk of the rotor can be varied to adjust the rate of feed. The movement of the rotor prevents clogging and a uniform rate of feed can be maintained up to 70 to 80 lb. per hour.

This huller has been used to determine kernel percentage on 100-gm. samples of sunflower seed (2), and in conjunction with a small oscillating gravity table it is in regular use for the separation of meats for oil expression. With this latter equipment it is possible to separate the hulled material sharply into hulls, meats, and a small percentage of unhulled seed in a single operation. Where a close separation is required, in the preparation of a hull-free meat for human consumption, the authors favour the gravity separation. Using this method small samples for nut substitutes and the production of sunflower butter have been prepared.

Performance

The efficiency of any impact huller will depend on the velocity of impact and also on the moisture content of the seed. The performance of the hulling unit was, therefore, tested at various rotor speeds and moisture levels. A portion of seed was run through the huller and the percentage hulling determined by separating the unhulled seed, computing the portion hulled, and expressing this quantity as a percentage of the original sample weight. Broken meats were determined by collecting the hulled meats, separating all portions smaller than $\frac{3}{4}$ of a whole meat, and expressing this quantity as a percentage of the meats actually recovered.

Since the object of the tests was to determine conditions of moisture and impact velocity for maximum hulling and minimum breakage of meats, the

results are recorded graphically to illustrate trends in the data. Regular relations were obtained, which permit estimation of performance at a given rotor speed or moisture level.

Sunflower Seed

Material

Two representative samples of sunflower seed, one of Mennonite and the other of the Sunrise variety, were selected for test. They were cleaned to a dockage-free basis in a fanning mill using the official No. 24 and No. 12 screens for Mennonite and No. 18 and No. 10 screens for Sunrise. Bushel weights were 26.9 and 31.7 lb., respectively, for the varieties. These values are very close to the mean bushel weights for commercial samples from the 1943 crop (2).

Method

Each parcel of seed was subdivided into three large samples that were adjusted to moisture levels of 8.1, 10.4, and 11.9%, respectively. This range was selected to include the moisture level 9.5%, which has been established for straight grade seed (1, 3).

After the seed had attained moisture equilibrium, 200 gm. aliquots from each main sample were hulled at rotor speeds of 2200, 2600, 3000, and 3400 r.p.m. Percentage hulling and broken meats were determined as a check on operating efficiency.

Effect of Impact Velocity and Moisture Level

The effect of varying impact velocity, on the percentage of seed hulled and meats broken, is shown for three moisture levels in the two graphs at the left of Fig. 2. Values plotted are means for the two varieties. As the rotor speed was increased, percentage hulling increased rapidly till a value of approximately 80% was reached. Below this value the relation between speed and hulling was almost linear, while above it a sharp reduction in hulling with increased speed occurred. Broken meats increased slowly with initial increase in rotor speed but at higher speeds breakage increased at an accelerated rate.

The effect of varying moisture level is shown in the two graphs at the right in Fig. 2. Percentage hulling at any given rotor speed decreased with increasing moisture content of the seed. At 2200 r.p.m. this decrease was almost linear but at higher speeds the relation is curvilinear. Relations between moisture content and breakage of meats showed a trend in the opposite direction. Low moisture favoured high breakage, which decreased sharply with increased moisture content.

These data indicate that, at a rotor speed of 3000 r.p.m. and a moisture content of 9.5%, 90% of the seed could be hulled with only 7% of broken meats. The mixture was separated in a fanning mill without excessive loss and the material going to the oil press contained only 5% of hulls.

Effect of Variety

Differences in the behaviour of Mennonite and Sunrise seed are shown in Fig. 3 as means over the three moisture levels for each variety. Percentage

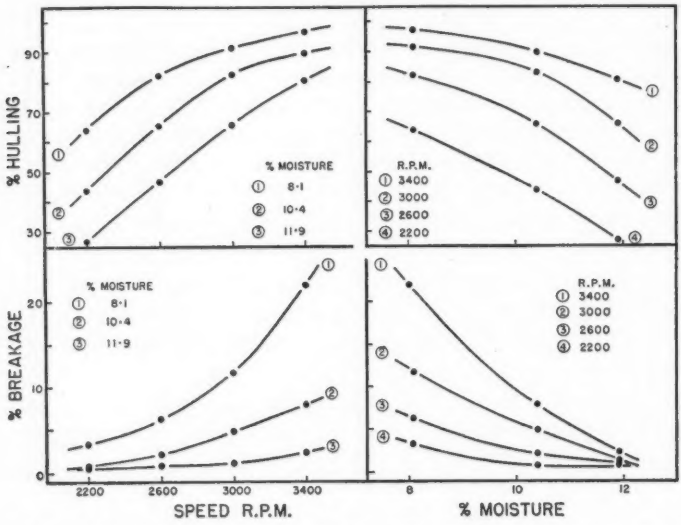

FIG. 2. *Relations of percentage hulling and meat breakage with impact velocity and moisture content for sunflower seed.*

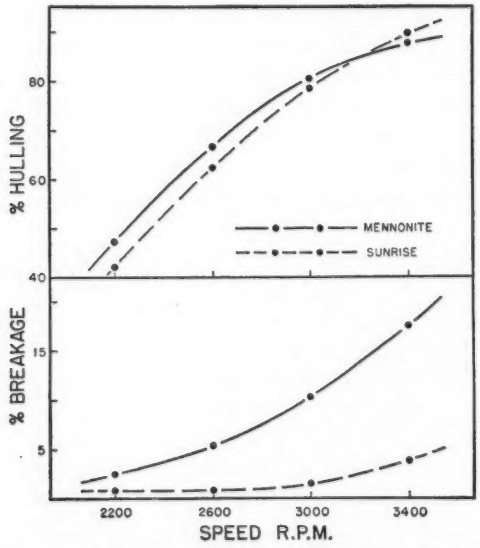

FIG. 3. *Effect of variety on percentage hulling and meat breakage for sunflower seed.*

hulling showed little difference but it is significant that the curves in the upper diagram cross at higher rotor speeds. Mennonite is more variable in seed size than Sunrise and the larger seeds are hulled more readily at low rotor speeds. At higher speeds the smaller Mennonite seeds are more difficult to hull than the corresponding fraction of the Sunrise seed.

An examination of the unhulled seed showed that most of it had struck the hulling baffle point first. In most cases the hull had been cracked and the seed hulled very readily on a second pass through the huller. This factor contributes to the differences between the varieties. The small Mennonite seed tends to be long and thin with a sharp point; consequently, it resists impact at the point of the seed more than Sunrise, which tends to be plumper and rounder.

The most striking difference between the varieties is in the percentage of broken meats. The kernel of Mennonite is oval and flat and in poorly filled seed is of paper thinness. When the seed is subjected to impact the kernel breaks readily. In Sunrise the kernel is rounder and even in small and poorly filled seed it retains its roundness. This characteristic shape makes the kernel less fragile and it stands the shock of impact with substantially less breakage than Mennonite seed.

Oats

Material

Two samples of oats were selected for test. One was obtained from a local firm as No. 1 feed oats and had a bushel weight of 40 lb. The other was a sample of Banner oats of seed grade that had a bushel weight of 41.8 lb. These samples were tested as received and both of them contained some thin and greenish kernels. A sample of oats being used by a local firm for hulling showed a bushel weight of 46 lb.

Method

The samples were treated as indicated in the section on sunflower seed with the exception that moisture levels of 7.1, 10.4, and 13.9% were selected for test. Since oats require a more severe impact, rotor speeds were increased to 3000, 3400, 3800, and 4000 r.p.m. Hulling and breakage of meats or groats were estimated in the same manner as for sunflower seed.

Results

Since the two samples of oats did not differ significantly, the values obtained were averaged and the results are presented graphically in Fig. 4. A comparison of these data with those given for sunflower seed in Fig. 2 shows a very close similarity. The effects of changes in impact velocity and moisture level show the same trends in percentage hulling and breakage of kernels.

Discussion

It is obvious that, as impact velocity increases, the percentage hulling approaches a value of 100% for both sunflower seed and oats. However, this is accompanied by a sharp rise in breakage of meats that complicates the

problem of separation. If the moisture level of the seed is raised there is a marked reduction in breakage of meats, but the hull becomes tough and the percentage hulling falls off sharply.

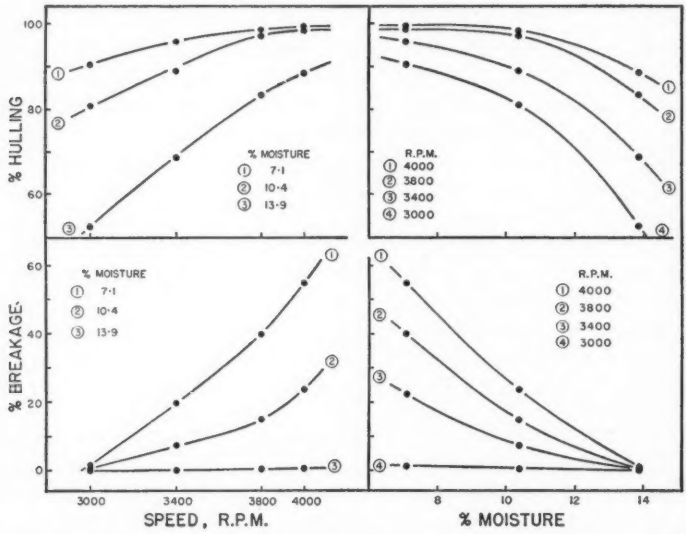

FIG. 4. *Relations of percentage hulling and meat breakage with impact velocity and moisture content for oats.*

To increase the hulling efficiency the hulls should be dry and brittle while the meats should be tough and resistant to impact. This suggests that improved efficiency could be obtained by taking seed at or near the moisture level for safe storage and subjecting it to a short, sharp flash drying immediately prior to hulling. The unit described has proved very useful in laboratory studies and investigations are being continued to increase its efficiency.

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A SMALL SEPARATOR FOR THE RECOVERY OF MILKWEED FLOSS AND SEED

PART I. CONSTRUCTION AND OPERATION[1]

By D. H. Hamly[2]

Abstract

A small separator for recovery of milkweed floss and seed was constructed in answer to the demands of the war research project *BE*-1. Its performance encouraged the development of the Model IV separator as a means of facilitating the utilization of wild milkweed in marginal farming areas. The construction, operation, and performance are described. The machine has a capacity of 12 bu. of dried pods per hour. A single passage through the machine under standard operating conditions yields 83 to 92% of the floss content as a high grade product and 95 to 98% of the seed. Data from this model have been used in designing a portable continuous production model with a capacity of 20 bu. per hour.

Introduction

In 1942, in view of the scarcity of rubber resulting from war in the Pacific, a group* in the Department of Botany, University of Toronto, undertook an investigation of plants producing substitute rubbers. One of these plants, *Asclepias syriaca* L., the common milkweed, produces in addition a floss that can be used as a buoyancy and insulation agent as an efficient substitute for Java kapok, also in short supply. The author's part in this investigation included the development of a mechanical separator when manual separation methods failed to produce sufficient seed for experimental plantings in the limited time available.

The first separator performed in a way that indicated that a small machine might be developed with sufficient capacity to be an economic answer to the problem of the ready salvage of milkweed growing on waste lands and marginal farms. It is considered that the laboratory machine known as Model IV, described in this paper, demonstrates that this is feasible.

The milkweed plant has been the subject of test and experiment for more than 200 years, and the products that have aroused the greatest interest are the floss, the stem fibre, and the leaf rubber. Interest in the use of milkweed seed oil is a recent development. The literature to October, 1943, has been well reviewed by Whiting (11). Senn (9) and Lanson and others (7) have reported developments to February, 1945, and Krotkov (6) gives a complete review of the recent extensive Russian literature.

The lustrous milkweed floss has aroused much interest from early times and has been compared with cotton and kapok in respect to structure, physical

[1] *Manuscript received April 11, 1945.*
Contribution from the Department of Botany, University of Toronto, Toronto, Ont.

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and chemical properties, handling, and uses. Table I is a summary of this information from the literature.

Previous studies clearly indicate that while the floss is not suited for textile use, as it lacks the curliness, elasticity, and strength required for spinning, it is ideally suited for buoyancy and insulation purposes because of its space-filling and chemical properties. The data indicate that the structure of the milkweed pod (follicle), the cotton boll (capsule), and the kapok pod (follicle) are as different as the fibres they enclose. Consideration of such facts has stimulated new approaches to the mechanical problems of separation. Dr. Boris Berkman (1)* has developed several large milkweed gins, and these have been used in the organization supported by the United States Department of Agriculture that gathered milkweed pods from 26 states and several Canadian provinces and processed about 1,500,000 lb. of floss in the past season (7).

Utilization of milkweed products is limited by competition with many other products, and Miss Whiting (11) concluded her review of the literature by stating that "recently emphasis has been placed on the importance of these secondary products in any effort toward making milkweed a paying crop." Likewise, economy in handling the crop is an important factor. It has been considered since the inception of our undertaking that the development of a separator small enough to be portable and efficient enough to give inexpensive separation was desirable. A similar problem existed in the threshing of grain crops in the hill farm areas of the South, in the United States. The Tennessee Valley Authority promoted the development of a small portable grain thresher and now some 500 are in use, bringing greater incomes to many farms (10).

During the development of the milkweed separator, it was found that separation of floss from seed was most efficient when both were still held within the closed or only partially opened pod. The best results were obtained with pods picked just before opening, dried in racks indoors or in onion bags outdoors with a good circulation of air around them, and stored in a dry place, preferably with a relative humidity of 50 to 60%. However, pods picked earlier or later, dried, and stored under conditions favourable to the development of fermentation and mildew have given good results provided that they were dry at the time of separation.

Separation was not satisfactory when floss and seed were free from the pods, as battering by passage between the blades of propeller or sirocco fans or by blowing against rough surfaces are not efficient for separation. These methods require many blows to break off seeds, and these blows fragment the heads of floss and break down the fibres. When seeds and floss are still firmly held within the pods, the seeds can be broken off the floss heads by any one of several kinds of manipulation: rolling between the hands, between the hand and a flat surface, rolling with a roller while laid on a flat surface, or passing

** On May 8, 1945, two additional patents describing new methods and a new type of gin were granted to Dr. Boris Berkman and associates. They are U.S. Patents Nos. 2,375,186 and 2,375,187.*

TABLE I

COMPARATIVE INFORMATION ON MILKWEED, KAPOK, AND COTTON

——	Milkweed	Kapok	Cotton
Family	Asclepiadaceae	Bombacaceae	Malvaceae
Specific name	*Asclepias syriaca*	*Ceiba pentandra*	*Gossypium* spp.
Pod			
Type	Follicle	Follicle	Dehiscent capsule
Origin of hair	Seed, point near hilum	Hull, inner surface	Seed coat
Hair			
Description			
Diameter	Tip 8μ, base 40μ	10 to 35μ	10 to 30μ
Length	25 to 45 mm.	8 to 32 mm.	15 to 50 mm.
Wall character	Primary and secondary layers only	Primary and secondary layers only	Multiple spiral layers
Wall thickness	0.7 to 2μ	Max. about 2μ	Max. about 10μ
Wall shape	Tubular	Flattened and folded tube	Empty, twisted fire hose
Lumen	Open	Largely closed	Closed
Chemistry			
Wax	Present	Present	Present
Cutin	Present	Present	Present
Cellulose α	About 34.86%	About 35.12%	About 90.51%
Furfural	19.07%	15.05%	0.80%
Lignin	About 21.16%	About 13.5%	0.63%
Ash	1 to 3.5%	1 to 3.6%	About 1.6%
Seed			
Shape	Slender, with wings	Pea-shaped	Pear-shaped
Size	With wings $\frac{1}{32} \times \frac{1}{16} \times \frac{1}{8}$ in.	About 4 mm. diameter	$\frac{1}{4}$ to $\frac{1}{2}$ in. diameter
Hair	Arises near hilum		Over surface
Method of separation and collection			
Pod	Picked	Picked	Not picked
Contents	Machine separated	Hand picked	Picked
Fibre from seed	Rolled	Shaken apart	Ginned
Fibre from placenta	Tossed, tumbled out	Shaken apart	Machine cleaned
Fibre from hull	Tossed, tumbled out	Hand picked	Hand separated
Usefulness			
Hair			
Spinning	Useless	Slight	Most important
Buoyancy	Very good	Very good	Useless
Pillows	Usable	Commonly used	Rarely used
Mattresses	Usable	Commonly used	Commonly used
Insulation—Heat	Very good	Very good	Used
Insulation—Sound	Probably good	Very good	Used
Seed			
Oil	Baking enamels	Good, various uses	Good, various uses
Cake	Fertilizer (?)	Edible, fertilizer	Good, various uses
Hulls			
Gum	Probably usable	No information	Not used
Authority	Whiting (11) Lanson (7) Gerhardt (3) Rheineck (8)	Zand (12) Whiting (11) Gerhardt (3)	Brown (2) Hayward (5) Whiting (11) Gerhardt (3)

between pairs of rubber rollers. This rolling breaks away all seeds from the heads of floss excepting the small, immature seeds. Rolling also fractures the rather brittle dried hull, tends to entangle hull fragments with the floss, and leaves the product a rather flattened mass of slowly expanding material. Tossing and tumbling this mass of material in a gentle current of air releases the floss, and screening the remaining mixture of seeds and hull materials completes the essentials of separation.

Many variations of these methods have been tried, the more promising being used in the four separator models that have been constructed. The conclusions reached are summarized in the following operating principles:

1. That separation of the seed from the floss can be brought about while both are still retained within the hull, by combined rolling and flexing of the pods.

2. That most, but not all of the recoverable floss can be released from the fractured hulls and the ribs of the placentae by gentle beating and tossing in a current of air.

3. That the practically complete separation of floss from the coarsest and intermediate waste materials can be achieved by tumbling the mixture upon a moving screen in a current of air. The practical type of screen motion is rotatory.

4. That sufficiently complete separation of floss from the finest elements of debris and from occasional floss heads carrying seed can be effected by the differentiating action of a slow, mildly turbulent air stream.

5. That floss breakage can be kept at a minimum by threshing dried pods having a relatively high moisture content and by reducing air velocity and the violence of mechanical handling as separation proceeds.

Construction and Operation

All parts of the Model IV separator, including the five motors and two fans, are assembled within a floor space of 5 × 9 ft., with a head room of 7 ft. They are readily assembled, taken down, transported, and each separate unit can pass through a 36 in. doorway.

The arrangement of the several units when assembled is shown in Fig. 1. The left side elevation shows the hopper and under it, one above the other, the rolls, the spiral beater, the beater screen, and the beater trap (A); the screening tube cover (B), enclosing the screening tube (C), which has within it the screening tube core (D), two traps, the seed trap (E), and the hull trap (F), and the stream-lining cone (G) in the discharge throat of the screening tube cover; the separator (H) and the discharge aperture (I) into the floss trap (J).

The pods are first fed into the rolling unit where the necessary rolling and bending are applied. Thence they drop into the beater unit where the fractured pods are tossed in a current of air entering by port X and so are freed of the major part of the floss and seed. The materials then pass into

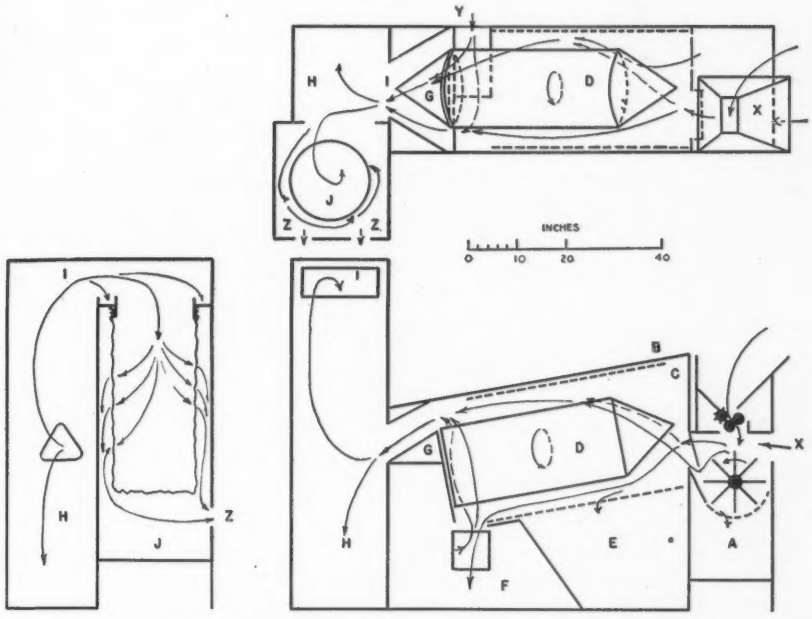


FIG. 1. *Diagrammatic sections of the Model IV thresher showing flow plan of air and materials.*

the screening tube unit in which the hull materials are further freed of adherent floss and most of the remaining seed by tumbling in an air stream. Only floss, floss heads with seed attached, and light debris pass into the separating and floss-trap units. Here the light, air-borne debris is settled out and the floss passes to the retaining bag of the floss trap. Though five motors are used the total power requirement is less than 1 h.p. Except for the screens, their frames, and the drive and gears, the construction is of paper board on wood framing.

The Rolling Unit (Fig. 2)

This consists of a spiked, rope-covered feed roll (J) and the floating (K) and the fixed (L) thick rubber rolls. These rolls are driven by a continuous chain running over the driving sprockets (B, C, and D), the idling sprockets (E), and the countershaft sprocket (F). The use of chain and the appropriate number of teeth on each of the driving sprockets ensures that the surface speed of each of the rolls is the same. The floating roll is mounted in a pair of supports (G) permitting the adjustment of the spring pressure on the rolls. The feed roll is carried in supports that are mounted on the shaft of the fixed rubber roll. An adjustment (H) to a clearance of $\frac{3}{4}$ in. from the floating roll is ordinarily satisfactory. The rubber rolls rotate at 58 r.p.m. (revolutions per minute).

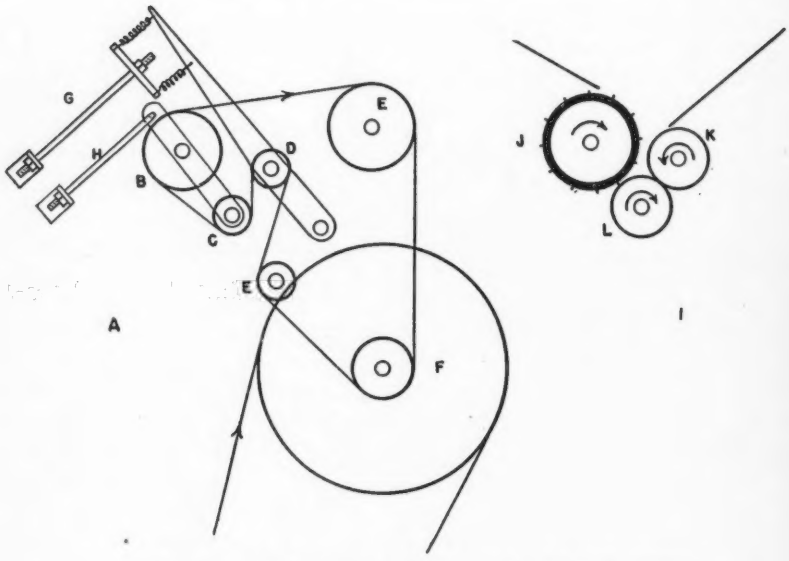
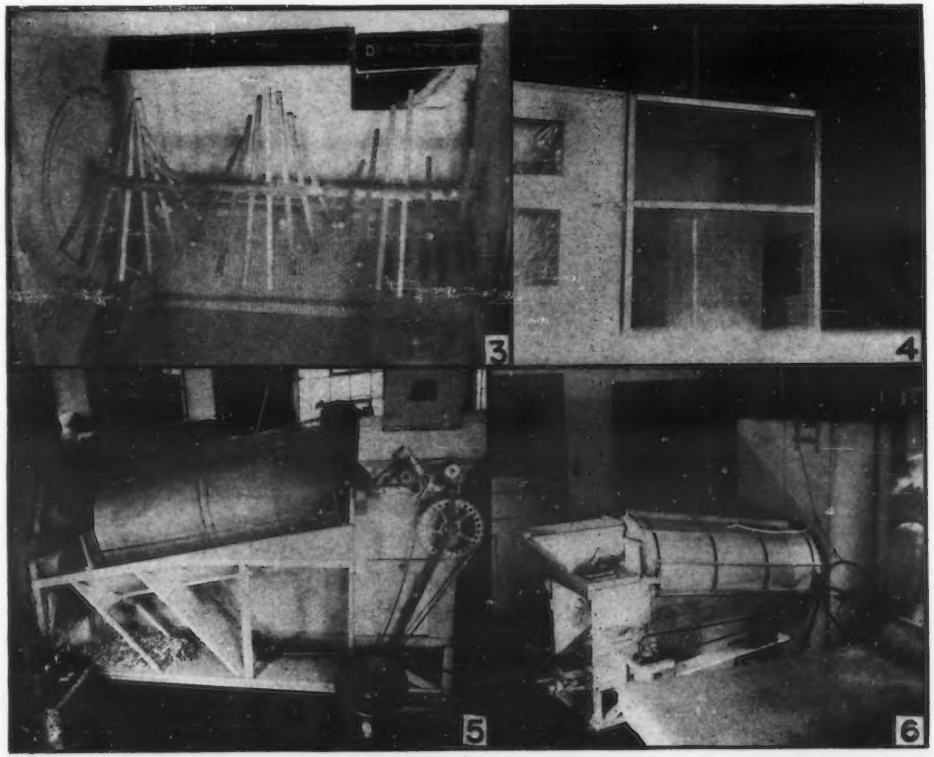


FIG. 2. *The rolling mechanism: the drive (A) and the rolls (I).*

Using the full roll length of 10½ in. the capacity of this unit is greatly in excess of that of the other units of the machine, but at rates of feeding higher than 15 bu. per hour the rolling pressure on each of the many pods passing through at one time is not high enough to effect complete separation of seed from floss. Restricting the effective length of the rolls to 3 in. by an aperture plate so that pods pass through not more than two at a time allows adequate pressure at a rate of about 12 bu. per hour, which is within the capacity of the other units. Ordinarily a maximum pressure of 140 lb. is applied, under which the hull is fractured, the placenta is undamaged, a limited breakage of seed wings occurs, and about one or two seeds in 5000 pass through with the floss head still attached.

The Beater Unit (Figs. 2, 3, and 5)

This is a box, divided into upper and lower parts by a curved, ¼ in. mesh screen, with a large door in the front face giving access to both parts. (To permit adequate display, the photographs show the screen dropped and the door removed.) In the upper section, housing the beater, there is an opening in the ceiling for the admission of rolled pods, an opening in the upper left corner of the door for the admission of air, and two adjustable discharge openings in the back wall. The long floss port is closed by a hinged door (marked "Floss port" in Fig. 3) and the debris port is shown partially closed by the vertically sliding door (marked "Debris port" in Fig. 3). Most of the air-borne floss is carried out underneath the floss port door, the seeds and fine debris pass through the screen, and the remaining materials are thrown



FIGS. 3, 4, 5, and 6. *The open beating chamber, the floss trapping tower, and the left and right sides of the separator.*

out the debris port by the rotating beater, which also taps and vibrates the screen for better clearing. The lower compartment of the beater unit receives the seeds mixed with any debris that may pass the screen.

The beater itself is a shaft pierced by 23 dowels arranged to form a double, right-hand spiral (Fig. 3) from the left end to a point opposite the hull port, and a double left-hand spiral of the same pitch thence to the right end of the shaft. The beater, rotating at about 360 r.p.m., tosses the heavier materials, and in so doing moves them toward the debris port through which they are thrown by the reversed spiral at that point.

Air is drawn through at 267 c.f.m. (cubic feet per minute). This rate is sufficient to overcome the centrifugal air currents produced by the rotating beater and to prevent the discharge of materials at the intake port in the access door. Air intake and beating time and hence also the amount of material present in the beating chamber are controllable by adjusting the dimensions of the exit ports. The narrow floss port is seldom adjusted. Diminishing the aperture of the hull port renders the fragmentation of the hulls excessive and increases slightly the floss breakage, while enlarging the port lowers breakage and increases the beating capacity but also lowers the efficiency of floss recovery. An intermediate size with an area of 20 sq. in. has been adopted as standard. Analogous results follow from rates of feeding in excess of about 200 pods per minute under standard conditions. Short periods of overload, of one minute or less, are of no consequence, but floss quality is impaired and some floss is lost when overloading lasts four or five minutes. It is difficult to assess the degree of impairment when the floss is degraded by the presence of broken floss heads, but the loss of broken floss that tends to lodge in the beater and in the seed trap is readily measurable. With serious overloading the highest observed loss was 2% of the total floss.

The screen lies one-half inch below the tips of the beater rods except at the right-hand end where a striking-plate lies on the screen. The tapping of the rods on this plate vibrates the screen, keeps it clear of seed and fines ,and assists in the rapid discharge of the coarse hull materials. Much the larger part of the seed accumulates in the lower compartment of this unit. It is contaminated by more or less debris, depending upon the amount of overloading, but this is readily removed in a fanning mill.

The Screening Tube Unit (Figs. 5 and 6)

The essential feature of this unit is a tube of $\frac{1}{4}$ in. mesh screen 25 in. in diameter and 42 in. long (C), surrounding a conical pointed core 16 in. in diameter (D) and separated from it by a uniform annular space. Both are mounted on a shaft sloping at $8\frac{1}{2}°$, and supported over two traps, one to receive the screened materials (E) and the other for the large hull materials discharged at the open lower end (F). The whole is enclosed by a housing that has a removable cover and two access doors. Within the cover, streamlining surfaces and a half cone (G) form a throat for the discharge of air and air-borne material into the separating tower (H).

During operation the tube and core rotate at 12 r.p.m. and tumble the heavier materials discharged from the beater unit while these are exposed to the gentle air stream passing through the annular space. To prevent floss from lodging in the hull trap a jet of air blows into the mouth of the trap. This separates most of the small residue of floss from the hull materials and carries it above the baffle into the main stream of air-borne material passing through the streamlined throat to the separating tower.

The Separating and Floss Trap Unit (Figs. 1 and 4)

The separating tower is 6 ft. high and 20 in. square. The air stream enters from the screening tube unit through a triangular port, 70 sq. in. in area, excentrally placed in the front wall 26 in. above the base, and passes to the adjacent floss trap tower by way of a rectangular port in the side wall just below the ceiling. The principal features of the separating tower are, first, the change in the mean velocity of the air stream, which enters at 14 f.p.s. (feet per second) and rises at 2 f.p.s. and, second, the presence of considerable turbulence produced by the 90° change in direction of the air stream in the non-streamlined tower. The swirls created by turbulence throw out of the main air stream the heavier air-borne materials, and the slow vertical air stream separates the rising floss from the seed-bearing heads of floss, which are too heavy to float at this velocity. While the separation is not absolutely complete, there is only about 0.03% by weight of debris and seeds carried into the floss trap. Debris is removed from the bottom of the separator tower through the access door near the base.

The floss trap (J, Fig. 1) is a tower 24 in. square and 6 ft. high immediately adjoining the separating tower, with the intake port in the common wall, and two exhaust ports, one adjustable, at the bottom of the opposite wall. This tower is divided just below the intake port by a horizontal partition (Fig. 4) pierced by an aperture 18 in. in diameter (I, Fig. 1). A metal collar projecting above and below forms a trap above, catching fine debris thrown out of the swirling air stream as it passes through the aperture. From the lower projection are hung cotton mesh bags of 5 cu. ft. capacity. Bags of 1 cu. ft. capacity, 10½ in. in diameter, can be hung from an adapter inserted into the aperture, for collecting small quantities, as of pure variety floss.

Air Flow

Critical limits were placed on the design by the balance required between two necessities, the separation of air floatable debris from the floss and the large volume of air required to float the floss. The former requires low velocities and mild turbulence, the latter needs a broad cross sectional area across the air stream, therefore effective use of all space within the separator to keep spatial requirements at a minimum.

Attention was also given to air flow characteristics under various conditions of operation with a view to defining a standard mode of operation and deciding upon a suitable index of the deviation from standard conditions during a run.

Standardization was considered necessary so that inherent differences among the varieties of milkweed would be accurately indicated by the products of threshings.

Air is drawn through the machine by two fans* and is so controlled that any rate from zero to 450 c.f.m. can be obtained. It is discharged from the fans through a 10 in. pipe outside the building, along with its burden of extremely fine, irritating dust. Two air intake apertures are provided, as noted, one in the beater access door, the other in the right side of the screening tube unit at the mouth of the hull trap. Linear velocity varies widely from one point to another in the separator, and during operation all velocities bear a relationship to one another as fixed by the volume of air handled per minute. The basic requirement is that the vertical velocity in the separating tower should not be greater than 2 f.p.s. in order that the heavy floss heads still carrying seeds will settle out, and this velocity limits the volume of air moving through the tower to 355 c.f.m.

When this had been determined, experimental work was directed to standardizing conditions in other parts of the machine so that each unit would perform efficiently. In the case of the beater unit it was established that, using the standard initial volume of 267 c.f.m. of air, the most efficient separation of floss from hull materials was obtained by rotating the beater at 360 r.p.m. and so producing a peripheral velocity of 18 f.p.s. In the screening tube unit, the same volume of air moving through the annular space between the screen and core at 1.7 f.p.s. over the mass of materials tumbled on the screen rotating at 12 r.p.m. moves just fast enough to blow out gently most of the remaining floss and keep it air-borne. At the discharge end of the screening tube this velocity is too low and the second stream of air entering by port Y at a velocity of 4 f.p.s. and a volume of 88 c.f.m. is introduced to prevent floss from lodging with the hull materials. The combined air stream, of 355 c.f.m. passes to the separating tower through the constricting throat, which raises its velocity to 14 f.p.s. on discharge.

Measurements of air flow were made with a calibrated Negretti and Zambra Air Flow Meter. The reduction in pressure at the constricting throat was measured with a double tube gauge filled with 95% alcohol sloping at a small angle that gave a constant of 1 : 149.1. Fig. 7 shows a graph of the relationship between the pressure reduction at the throat and the volume discharged through the 10 in. discharge pipe as determined by a series of simultaneous observations.

It soon became apparent that important changes in performance were related to variations in air flow and it was found that both below and above the limits of 328 and 382 c.f.m., respectively, there was a serious falling off in performance. The sloping gauge has proved its usefulness in two ways, first in maintaining standard conditions well within critical limits, as $\frac{1}{8}$ in. gauge change indicates approximately 7 c.f.m. air flow change; and second,

** Two Tordoff No. 4 Furnace Blowers with 3 in. by 12 in. casings turning at 1425 r.p.m. were used and provided the desired volume and air pressure.*

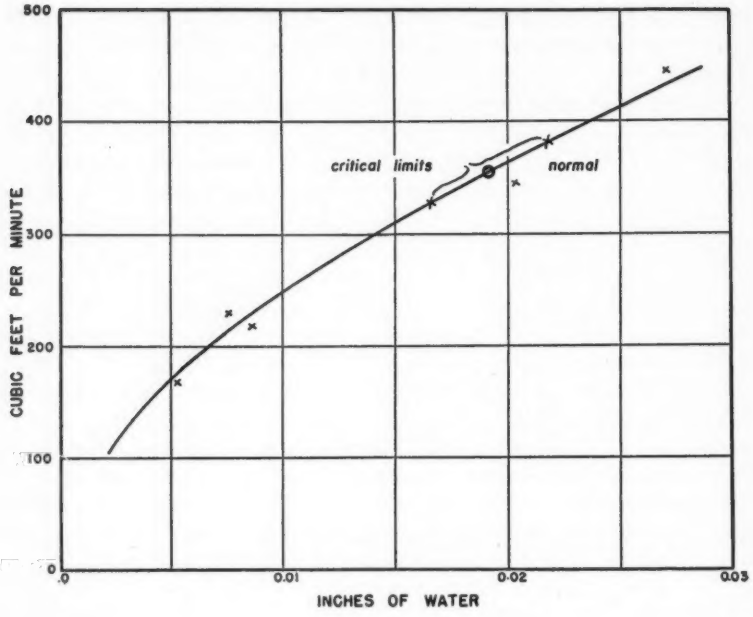


FIG. 7

by indicating quickly significant changes in operating conditions. For instance, steadily increasing gauge readings indicate that the separator is overloaded and requires a reduction in feeding rate, while steadily decreasing readings indicate that the floss bag is becoming overloaded, and readings that do not bear a normal relationship to fan control settings indicate open access doors or blocked ports.

Performance

The capacity of the separator to do useful work in an economical and practical way has been tested in many qualitative and quantitative experiments. Performance was critically examined in respect to: first, quality of product; second, capacity per hour; third, percentage efficiency for one operation; and fourth, percentage recovery.

During the separator's development, floss quality received first consideration, and it was not until floss quality was consistently high and capacity per hour was reasonable that quantitative experiments were commenced. Floss is recovered mainly as intact heads with relatively small amounts of fragmented floss. Usually the floss contains a few seeds and a trace of debris, but the amount of contamination is small, as only 1 or 2 in 5000 of the seeds originally present in the pods passes through to the floss bag. While these seeds and the traces of debris are unimportant, the dark colour makes them conspicuous.

While maintaining optimum quality of product, threshing capacity is estimated to be 12 bu. (60 lb.) of pods per hour of continuous production, based on performance during the threshing of 1- to 3-bu. lots of pods. Estimation is necessary since the traps in Model IV are small and cannot be emptied during operation without seriously disturbing circulation of air and materials through the separator. Higher capacity is obtained by sacrificing quality and percentage efficiency; higher quality and percentage efficiency can be obtained by very slow and careful feeding of pods.

Performance is limited by the working capacity of the beater, screening tube, and separating tower, which, when overloaded, indicate it by lower quality and decreased efficiency. Size is considered to be the principal limiting factor, and in the design of Model V the dimensions of these units have been increased. Performance is also affected by the condition and type of pods. It is improved somewhat by storage of pods in air of high relative humidity and by using those varieties of pods that have thin and brittle hulls. However, such changes are relatively unimportant in the threshing of mixed, random-collected lots of pods. Immature and badly mildewed pods reduce capacity considerably.

Percentage efficiency is given by the ratio:

$$\frac{\text{Weight of component separated during one operation} \times 100}{\text{Total weight of component in sample}}.$$

It is determined by a complete assay of every trapped fraction of the original pods in terms of the component parts. Percentage efficiency has been relatively steady and has tended to increase as methods of operation have improved. An average of 83.3% for floss (min. 75.3%, max. 91.5%) and 97.1% for seed (min. 94.7%, max. 98.0%) has been obtained. These values are for bagged floss and for seed recovered by cleaning materials from the beater and seed traps. Efficiency varies with pod condition and variety but it is probable that future threshings will continue to show smaller variations as pod condition becomes more nearly uniform and as other more favourable conditions of threshing become definitely standardized.

Percentage recovery is given by the ratio:

$$\frac{\text{Weight of component separated} \times 100}{\text{Weight of pods threshed}}.$$

It is calculated from figures obtained for the determination of efficiency. Percentage recovery has shown an average of 23.0% (min. 20.5%, max. 26.0%) for floss and 37.3% (min. 32.9%, max. 44.0%) for seed. These variations were noted in five experimental threshings: four lots of clone variety pods and one lot of random-collected pods threshed under uniform conditions. While these variations are marked they are likely to be increased when additional varieties are threshed since they are related to discernible biological differences in all parts of the milkweed plant. In the examination of 24 different clone varieties from a limited area, marked differences in floss length and in the resistance of floss to breakdown have already been noted. When the survey

is extended to other areas it is expected that further evidence of biological variability in the wild stands will be obtained.

The quantitative results as calculated on a percentage recovery basis indicate that such figures can only be properly used in appraising the value of a given variety of milkweed plant and not as an index of the separator's ability to thresh. Appraisal of performance must be made on the basis of quality of product and percentage efficiency.

Continuous Production

Model IV is regarded as a good prototype of a small, continuous production separator, and data from this model have been used in the completed design for a Model V, with a potential capacity of 20 bu. (100 lb.) per hour of continuous operation. This larger capacity is to be obtained within the same floor space (9 × 5 ft.) by careful re-designing. Steel and sheet metal are to be used instead of wood and paperboard, one or two motors instead of five, and double instead of single traps. Simpler operation will be obtained through the use of an automatically feeding pod hopper and easily accessible controls. Such a machine could be transported by a small truck or trailer without disassembly and could be used wherever electricity or steady primary power is available.

Conclusion

A new machine has been described for the recovery of floss and seed from dried milkweed pods. The technique of separation has been based on principles developed from hand separation experiments. It has been found that high capacity and high efficiency can be obtained in a small machine. By simplification of the mechanical drive it has been possible to design a new model for continuous operation with considerably greater capacity, with similar efficiency, and at the same time sufficiently compact to permit transport by truck or trailer.

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